Attorney's Docket No. 015290-506

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of	**Mail Stop APPEAL BRIEF - PATENTS**
Ting Chien et al.	Group Art Unit: 1765
Application No.: 09/820,692	Examiner: KIN CHAN CHEN
Filed: March 30, 2001	Confirmation No.: 5245
For: PLASMA ETCHING OF DIELECTRIC LAYER WITH SELECTIVITY TO STOP LAYER	Appeal No.:

APPEAL BRIEF

Mail Stop APPEAL BRIEF - PATENTS
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This appeal is from the decision of the final Official Action dated December 14, 2004, and Advisory Action dated May 10, 2005, finally rejecting Claims 1-4, 7-12, and 14-27, which are reproduced as the Claims Appendix of this brief.

A check covering the $500.00 (1402) Government fee is filed herewith.

The Commissioner is hereby authorized to charge any appropriate fees under 37 C.F.R. §§1.16, 1.17, and 1.21 that may be required by this paper, and to credit any overpayment, to Deposit Account No. 02-4800.

I. Real Party in Interest

The present application is assigned to Lam Research Corporation.

II. Related Appeals and Interferences

The Appellants' legal representative, or assignee, does not know of any other appeal or interferences which will affect or be directly affected by or have bearing on the Board's decision in the pending appeal.

III. Status of Claims

Claims 5, 6, and 13 have been canceled, while Claims 1-4, 7-12, and 14-27 stand rejected and are being appealed. See attached Claims Appendix for a copy of the claims involved in the appeal.

IV. Status of Amendments

A Request for Reconsideration After Final Rejection was filed on April 27, 2005. An Advisory Action Before the Filing of an Appeal Brief dated May 10, 2005, maintained the rejection of Claims 1-4, 7-12, and 14-27, asserting that the request for reconsideration had been considered but did not place the application in condition for allowance.

V. Summary of Claimed Subject Matter

Independent Claim 1 recites a method of etching a dielectric layer (See, for example, 114 of FIG. 1A) with selectivity to an underlying stop layer (See, for example, 106 of FIG. 1A), comprising supporting a semiconductor substrate in a plasma etch chamber of a plasma etch reactor (700 of FIG. 7). The plasma etch reactor is a capacitively coupled plasma reactor having a powered showerhead electrode (712 of FIG. 7) and/or a powered bottom electrode (718 of FIG. 7), the substrate including a dielectric layer (See, for example, 206 of FIG. 2A) over a stop

layer. An etchant gas is supplied to the plasma etch chamber with the showerhead electrode. Openings are etched in the dielectric layer by energizing the etchant gas into a plasma state by capacitively coupling RF energy into the plasma etch chamber, the etchant gas comprising a hydrogen-free fluorocarbon gas represented by C_xF_y gas wherein $y/x \leq 1.5$, an oxygen-containing gas and optional carrier gas. The plasma etch reactor comprises a dual frequency capacitively coupled plasma reactor and RF energy is supplied at two different frequencies to either the bottom electrode or at different first and second frequencies to the showerhead electrode and bottom electrode. The pressure in the plasma etch reactor is 50 to 100 mTorr and temperature of the substrate support is +20°C to +60°C. (See, for example, Page 4, Lines 2-8 and Page 5, Line 15 – Page 6, Line 6).

Independent Claim 24 recites a method of etching a dielectric layer (See, for example, 114 of FIG. 1A) with selectivity to an underlying stop layer (See, for example, 106 of FIG. 1A), comprising supporting a semiconductor substrate in a plasma etch reactor (700 of FIG. 7). The plasma etch reactor is a capacitively coupled plasma reactor having a powered showerhead electrode (712 of FIG. 7) and/or a powered bottom electrode (718 of FIG. 7), the substrate including a dielectric layer over a stop layer. An etchant gas is supplied to the plasma etch chamber. Openings are etched in the dielectric layer by energizing the etchant gas into a plasma state, the etchant gas consists essentially of a hydrogen-free fluorocarbon gas represented by C_xF_y gas wherein $y/x \leq 1.5$, an oxygen-containing gas and optional carrier gas. The plasma etch reactor comprises a dual frequency capacitively coupled plasma reactor and RF energy is supplied at two different frequencies to either the bottom electrode or at different first and second frequencies to the showerhead electrode and bottom electrode. The pressure in the plasma etch reactor is 50 to 100 mTorr and temperature of the substrate support is +20°C to +60°C. (See, for example, Page 4, Lines 2-8 and Page 5, Line 15 – Page 6, Line 6).

Independent Claim 25 recites a method of etching a dielectric layer (See, for example, 114 of FIG. 1A) with selectivity to an underlying stop layer (See, for example, 106 of FIG. 1A), comprising supporting a semiconductor substrate in a plasma etch reactor (700 of FIG. 7). The plasma etch reactor is a capacitively

coupled plasma reactor having a powered showerhead electrode (712 of FIG. 7) and/or a powered bottom electrode (718 of FIG. 7), the substrate including a dielectric layer over a stop layer. An etchant gas is supplied to the plasma etch chamber. Openings are etched in the dielectric layer by energizing the etchant gas into a plasma state, the etchant gas consists of a hydrogen-free fluorocarbon gas represented by C_xF_y gas wherein $y/x \leq 1.5$, an oxygen-containing gas and optional carrier gas. The plasma etch reactor comprises a dual frequency capacitively coupled plasma reactor and RF energy is supplied at two different frequencies to either the bottom electrode or at different first and second frequencies to the showerhead electrode and bottom electrode. The pressure in the plasma etch reactor is 50 to 100 mTorr and temperature of the substrate support is +20°C to +60°C. (See, for example, Page 4, Lines 2-8 and Page 5, Line 15 – Page 6, Line 6).

VI. Ground of Rejection to be Reviewed on Appeal

Claims 1-4, 7-12, and 14-27 stand rejected under 35 U.S.C. § 103(a) over U.S. Patent No. 6,451,703 ("Liu"), assigned to Applied Materials, Inc., in view of U.S. Patent No. 6,228,438 ("Schmitt").

VII. Argument

A. <u>Legal Precedent Applicable to Apparatus Features in Method Claims</u>

The Advisory Action contends that "apparatus limitations do not have weight in [a] process claim, unless they affect the process in a manipulative sense." (Advisory Action at Page 2). However, patentability of a method claim can be based on the structure used, if the structure affects the method steps. *Leesona Corp. v. United States*, 185 USPQ 156, 165 (Ct. Cl. Trial Div. 1975).

B. <u>Legal Precedent Applicable to Obviousness Rejections</u>

In order to establish a case of *prima facie* obviousness with respect to claimed subject matter, the Patent Office must establish (1) "some suggestion or motivation in the references themselves or in the knowledge generally available to one of

ordinary skill in the art, to ... combine the reference teachings"; (2) "a reasonable expectation of success"; and that (3) "the prior art ... references when combined ... must teach or suggest all the claim limitations." "The teaching or suggestion to make the claimed combination and the reasonable expectation of success must both be found in the prior art, not in applicant's disclosure" (citation omitted). *See* MPEP §§ 2143 and 2143.03.

Whether an art is predictable or whether the proposed modification or combination of the prior art has a reasonable expectation of success is determined at the time the invention was made. *Ex parte Erlich*, 3 USPQ2d 1011 (Bd. Pat. App. & Inter. 1986); MPEP § 2143.02.

A proposed combination of references is improper under 35 U.S.C. § 103 where the combination "would require a substantial reconstruction and redesign of the elements shown in [the base reference] as well as a change in the basic principles under which [the base reference] construction was designed to operate." *In re Ratti*, 270 F.2d 810, 813, 123 USPQ 349, 352 (CCPA 1959).

Furthermore, a prior art reference must be considered in its entirety, i.e., as a whole, including portions that would lead away from the claimed invention. *W.L. Gore & Associates, Inc. v. Garlock, Inc.*, 721 F.2d 1540, 220 USPQ 303 (Fed. Cir. 1983), *cert. denied*, 469 U.S. 851 (1984); MPEP § 2141.02.

C. Rejection of Independent Claims 1, 24, and 25 under 35 U.S.C. § 103(a)

1. Claimed Subject Matter

Independent Claims 1, 24, and 25 recite a method of etching a dielectric layer with selectivity to an underlying stop layer comprising supporting a semiconductor substrate in a plasma etch reactor. The plasma etch reactor is a capacitively coupled plasma reactor having a powered showerhead electrode and/or a powered bottom electrode and the substrate includes a dielectric layer over a stop layer. An etchant gas is supplied to the plasma etch chamber. Openings are etched in the dielectric layer by energizing the etchant gas into a plasma state. The etchant gas includes a hydrogen-free fluorocarbon gas represented by C_xF_y gas wherein $y/x \leq 1.5$, an oxygen-containing gas and optional carrier gas. The plasma etch reactor

comprises a dual frequency capacitively coupled plasma reactor and RF energy is supplied at two different frequencies to either the bottom electrode or at different first and second frequencies to the showerhead electrode and bottom electrode. The pressure in the plasma etch reactor is 50 to 100 mTorr and temperature of the substrate support is +20°C to +60°C.

2. **Examiner's Rationale for Modifying the Prior Art**

The final Official Action cites Liu as teaching,

> "in a method of oxide etching, ... a method of etching a dielectric layer with selectivity to an underlying stop layer. A semiconductor substrate is supported in a plasma etch reactor wherein the etch reactor is capacitively coupled plasma reactor including a showerhead electrode.[1] MERIE (a capacitively coupled plasma reactor) may be used. The substrate includes a dielectric layer (e.g., oxide layer) over a nitride stop layer. An etchant gas may be supplied to the plasma etch chamber with the showerhead. Etching openings may be performed in the dielectric layer by energizing the etchant gas into a plasma state. The etchant gas may comprise a hydrogen-free fluorocarbon gas represented by C_xF_y gas wherein $y/x < 1.5$. Liu also teaches that the chamber pressure may be varied from 25mT to 70 mT, which overlaps the claimed range." (citations omitted) (Final Official Action at Page 2).

As noted above, independent Claims 1, 24, and 25 recite, *inter alia*, a dual frequency capacitively coupled plasma reactor and RF energy is supplied at two different frequencies to either the bottom electrode or at different first and second frequencies to the showerhead electrode and bottom electrode. The final Official Action acknowledges that independent Claims 1, 24, and 25 "differ from Liu by specifying a dual frequency capacitively coupled plasma reactor including an upper showerhead electrode and a bottom electrode." (Final Official Action at Page 3).

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[1] This statement is incorrect. Liu does not disclose a plasma reactor having a showerhead electrode. Rather, Liu only discloses use of a quartz gas distribution plate through which process gas is supplied to the interior of the reactor. Replacement of the quartz plate with an electrode goes against the teachings of Liu and would require substantial reconstruction of Liu as explained below.

The final Official Action asserts that "Liu teaches using capacitively coupled plasma reactor including an upper showerhead electrode[2] and a bottom electrode." (Final Official Action at Page 3).

The final Official Action relies on Schmitt to show a dual frequency capacitively coupled plasma reactor including an upper showerhead electrode and a bottom electrode. The final Official Action asserts that it would have been obvious to one with ordinary skill in the art to incorporate those features as disclosed by Schmitt in the process of Liu in order to separately control the upper electrode and lower (bottom) electrode. (Final Official Action at Page 3).

3. **The Claimed Structure Affects the Method Steps of Independent Claims 1, 24, and 25**

As explained above, patentability of a method claim can be based on the structure used, if the structure affects the method steps.

The presently claimed capacitively coupled plasma reactor and showerhead electrode affect the method steps of independent Claims 1, 24, and 25, demonstrated by recitation of supplying RF energy "at two different frequencies to either the bottom electrode or at different first and second frequencies to the showerhead electrode and bottom electrode." Additionally, Claim 1 recites "supplying an etchant gas to the plasma etch chamber with the showerhead electrode" and "etching openings in the dielectric layer by energizing the etchant gas into a plasma state by capacitively coupling RF energy into the plasma etch chamber." It is respectfully submitted that these recited features must be given weight in the determination of the patentability of independent Claims 1, 24, and 25.

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[2] Rather than disclosing an upper showerhead electrode, Liu actually discloses that processing gases are supplied to a quartz gas distribution plate positioned in the roof of the chamber overlying the wafer. (Column 4, Lines 34-38). There is no disclosure in Liu of using a showerhead electrode. The addition of a showerhead electrode to a MERIE reactor as in Liu (filed March 10, 2000) was later patented by Applied Materials, Inc. the assignee of Liu (see U.S. Patent No. 6,894,245, which issued from an application filed October 22, 2001).

4. **Lack of Suggestion or Motivation Renders Prior Art Combination Improper**

As explained above, in order to establish a case of *prima facie* obviousness with respect to claimed subject matter, the Patent Office must establish, *inter alia*, some suggestion or motivation in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to combine the reference teachings. The teaching or suggestion to make the claimed combination and the reasonable expectation of success must both be found in the prior art, not in applicant's disclosure.

The Advisory Action asserts, "In this case, [the teaching, suggestion, or motivation to combine or modify the teachings of the prior art to produce the claimed invention is found] in the knowledge generally available to one of ordinary skill in the art because it is [a] notoriously well-known feature in the art." (Advisory Action at Page 2). As explained below, dielectric etching with a dual frequency capacitively coupled plasma reactor was not known until Appellant's invention.

Claim 1 recites a method of etching a dielectric layer with selectivity to an underlying layer and while Liu relates to etching dielectric oxides (Column 4, Lines 55-56 of Liu), Schmitt does not. The only mention in Schmitt of "dielectric" is in connection with a "dielectric" corrective layer used as a capacitor in series with a substrate and plasma to compensate for process uniformity. (Column 2, Lines 24-48 of Schmitt). Given that Schmitt does not relate to etching dielectric oxides, the final Official Action fails to establish the required motivation which would have led a person of ordinary skill in the art to consider Schmitt for purposes of modifying the dielectric oxide etch process of Liu.

Without knowledge of the claimed process, there is no objective teaching in the prior art which would have led one of ordinary skill in the art to combine Liu and Schmitt in the manner set forth in the final Official Action. That is, the final Official Action fails to establish any motivation for incorporating a "dual frequency" showerhead electrode (mentioned at Column 8 of Schmitt) in the MERIE reactor of Liu. As such, the rejection is improper and should be reversed.

Schmitt discloses various reactors for a multitude of purposes. Fig. 2 shows a reactor 1 having two spaced apart metallic electrodes 3, 5 neither of which is a

showerhead electrode since gas is supplied from a side of the reactor 1 by gas source 7. (See Column 21, Lines 54-60 and Fig. 2 of Schmitt). Fig. 10 shows a reactor having a showerhead electrode 3 and Fig. 12 shows a microwave reactor having a bottom electrode 126 but no showerhead electrode. Liu fails to disclose a showerhead electrode and Schmitt only discloses a showerhead electrode in one of the three reactors shown therein. As such, the combination of Liu and Schmitt fails to suggest the process recited in Claim 1 using a dual frequency capacitively coupled plasma reactor wherein etchant gas is supplied to the chamber with a showerhead electrode and RF energy is supplied at two different frequencies to either a bottom electrode or at different frequencies.

As noted above, rather than disclosing a showerhead electrode, Liu actually discloses a quartz gas distribution plate. Replacement of the quartz gas distribution plate of Liu with a showerhead electrode goes against the teachings of Liu and would require substantial reconstruction of Liu. In particular, referring to FIG. 2, Liu discloses, "An RF power supply 42, preferably operating at 13.56 MHz, is connected to the cathode pedestal 38 and provides the only significant power for generating the plasma while also controlling the DC self-bias." (Column 4, Lines 22-25). According to FIG. 2 of Liu, the RF power is returned through the chamber side walls. Thus, replacing the quartz gas distribution plate with a showerhead electrode would change the principle of operation of the Liu reactor and require substantial modification of the reactor to avoid problems such as arcing within the gas injection ports.

Incorporation of a showerhead electrode in a MERIE reactor is the subject of U.S. Patent No. 6,894,245 ("Hoffman"), filed October 22, 2001, which is seven (7) months after Appellants' filing date. Hoffman discloses a plasma reactor for processing a semiconductor workpiece, which includes a reactor chamber having a chamber wall and containing a workpiece support for holding the semiconductor workpiece, an overhead electrode overlying said workpiece support, the electrode comprising a portion of the chamber wall, an RF power generator for supplying power at a frequency of the generator to the overhead electrode and capable of maintaining a plasma within the chamber at a desired plasma ion density level. The

reactor further includes a set of MERIE magnets surrounding the plasma process area overlying the wafer surface that produce a slowly circulating magnetic field which stirs the plasma to improve plasma ion density distribution uniformity. (Column 2, Lines 48-66).

Hoffman discloses that an MERIE reactor: (1) "is, typically, a capacitively coupled reactor in which HF frequency RF source power is applied to the wafer support pedestal and returned through the chamber ceiling or side walls," (Column 16, Lines 5-9) and (2) "requires the process gases to be fed from an overhead gas distribution plate or showerhead." (Column 17, Lines 41-43). As noted above, Liu discloses that the overhead gas distribution plate or showerhead is made of a non-conductive material, and Hoffman further discloses that in order to achieve the desired combination of a showerhead electrode with an MERIE reactor, the problem of the susceptibility of the capacitively coupled reactor of Hoffman to arcing within the gas injection ports in the gas distribution plate had to be solved. (Column 17, Lines 47-53).

Additionally, with regard to the contention in the Advisory Action that apparatus limitations do not have weight in a process claim, unless they affect the process in a manipulative sense, as is evident from Hoffman, the presently claimed apparatus limitations do affect the processes of independent Claims 1, 24, and 25 in a manipulative sense. In particular, Hoffman discloses that arcing and other potential issues are avoided though any of a combination of features, including putting the overhead electrode at a floating D.C. potential by capacitively isolating it from the coaxial tuning stub, providing capacitance between the plasma and the overhead electrode, and introducing a metal or ceramic "foam" layer between the coaxial stub and the capacitive layer lying between the electrode and the coaxial tuning stub. (Column 19, Lines 11-55).

Hoffman establishes that conversion of a MERIE reactor to one with an upper electrode requires substantial reconstruction and redesign of the MERIE reactor, so much that Hoffman was awarded a patent for the new combination. Because the new combination of a MERIE reactor with a showerhead electrode did not exist at the time of Appellants' filing date, it is respectfully submitted that the modification of

Liu proposed nit eh final Official Action would not have been obvious to a person or ordinary skill in the art.

5. **Lack of Reasonable Expectation of Success Renders Prior Art Combination Improper**

As explained above, in order to establish a case of *prima facie* obviousness with respect to claimed subject matter, the Patent Office must establish, *inter alia*, a reasonable expectation of success. Further, whether an art is predictable or whether the proposed modification or combination of the prior art has a reasonable expectation of success is determined at the time the invention was made.

In light of the later disclosure in Hoffman, specifically regarding solving the problem of the susceptibility of arcing within the gas injection ports in an electrically conductive gas distribution plate, it is respectfully submitted that the proposed selective incorporation of only the dual frequency feature of Schmitt in the process of Liu did not have a reasonable expectation of success at the time Appellants' invention was made. Moreover, as pointed out above, absent Appellants' disclosure, there is no objective teaching to combine Liu and Schmitt as proposed in the final Official Action.

6. **Requirement of Substantial Redesign and Reconstruction Renders Prior Art Combination Improper**

As explained above, a proposed combination of references is improper under 35 U.S.C. § 103 where the combination would require a substantial reconstruction and redesign of the elements shown in the base reference as well as a change in the basic principles under which the base reference construction was designed to operate.

In light of the disclosure in Hoffman, it is respectfully submitted that the proposed modification of the MERIE reactor of Liu is improper as the combination would require a substantial reconstruction and redesign of the MERIE reactor of Liu as well as a change in the basic principles under which the MERIE reactor of Liu was designed to operate. Because the quartz gas distribution plate of Liu may not be connected to a high frequency source as disclosed by Schmitt, it would be necessary

to replace the quartz plate of Liu with a showerhead electrode. This would result in substantial reconstruction and redesign of Liu's reactor introducing problems addressed in the later filed and subsequently issued Hoffman patent. Accordingly, the modification of Liu proposed in the final Official Action is improper.

7. **Teachings Away Renders Prior Art Combination Improper**

As explained above, a prior art reference must be considered in its entirety, i.e., as a whole, including portions that would lead away from the claimed invention.

Liu teaches away from the claimed pressure and temperature of independent Claims 1, 24, and 25. The final Official Action asserts that pressure and temperature

> "are recognized result-effective variables, and commonly determined by routine experiment. The process of conducting routine experimentations so as to produce an expected result is obvious to one of ordinary skill in the art. In the absence of showing criticality or new, unexpected results, it is the examiner's position that a person having ordinary skill in the art at the time of the claimed invention would have found it obvious to modify Liu by performing routine experiments ... to obtain optimal result in order to produce the best etched product achievable." (Final Official Action at Page 4).

a. **Pressure**

Liu teaches that "the chamber pressure should be no more than 40 milliTorr." (Column 11, Lines 45-47). Therefore, since Liu teaches an upper limit of 40 mTorr for a chamber pressure, and as independent Claims 1, 24, and 25 recite a pressure in a plasma etch reactor of 50 to 100 mTorr, which is clearly greater than Liu's upper limit of 40 mTorr, it is respectfully submitted that Liu teaches away from the presently claimed pressure of 50 to 100 mTorr.

The final Official Action asserts,

> "In an example of obtaining high oxide etch rate, Liu states that the pressure should [be] no more than 40 mT, it is simply an example under a given particular product requirement. In fact, Liu teaches that the chamber pressure may be varied from 25mT to 70 mT, which overlaps the claimed range." (Final Official Action at Page 6).

However, rather than teaching that the chamber pressure may be varied from 25 to 70 mTorr, Liu tested oxide etch rate and photoresist selectivity from 25 to 70 mTorr and concluded, "Clearly, operation at the lower pressure is desired for both oxide etch rate and photoresist selectivity." (Column 11, Lines 42-44). More specifically, Liu determined that for both high oxide etch rate and high photoresist selectivity, "the chamber pressure should be no more than 40 mTorr." (Column 11, Lines 45-50).

Accordingly, it is respectfully submitted that in the present case, increasing chamber pressure in Liu is not a recognized result-effective variable, which a person having ordinary skill in the art would have found obvious to modify by performing routine experiments, for achieving "the best etched product achievable" as alleged in the final Official Action (Final Official Action at Page 4). Rather, because Liu specifically teaches a chamber pressure of no more than 40 mTorr, after testing pressures in the range of 25 to 70 mTorr, Liu teaches away from the presently claimed pressure in a plasma etch reactor of 50 to 100 mTorr.

b. **Temperature**

Additionally, Liu states that "fluid cooling channels through the pedestal 38 maintain the pedestal at reduced temperatures." (Column 4, Lines 14-16). Liu discloses that "MERIE plasmas tend to produce a significantly lower electron temperature, thereby reducing the charging effect" (Column 6, Lines 34-36) and the only disclosed cathode temperatures in Liu are -20°C in each of Liu's examples (Columns 8-10, Tables 1-4). There is no suggestion in Liu to raise the pedestal temperature above -20°C to optimize etching results. As such, it is respectfully submitted that the final Official Action fails to establish temperature as a result effective variable and further, there is no suggestion in Liu to maintain the temperature of the substrate support between 20°C and 60°C, as recited in Claims 1, 24, and 25.

D. Rejection of Dependent Claims 2, 3, 8, 11, 12, 14, 18, 19, and 21 under 35 U.S.C. § 103(a)

1. Rejection of Claims 3, 19, and 21 under 35 U.S.C. § 103(a)

Claim 3 recites the method of Claim 1, wherein the stop layer is silicon nitride and the etch rate selectivity of the dielectric to the silicon nitride is at least 10. Claim 19 recites the method of Claim 1, wherein the etched openings open onto flat and corner portions of the stop layer, the dielectric layer comprises BPSG and the stop layer comprises silicon nitride, the etch rate selectivity of the BPSG to the flat and corner portions of the silicon nitride being at least 15. Claim 21 recites the method of Claim 1, wherein the etch rate selectivity of the dielectric to the stop layer is greater than 30:1.

The final Official Action asserts,

> "Dependent claims 3, 19 and 21 differ from Liu by specifying various etching selectivities. However, the skilled artisan recognizes that in plasma etching, changing the flow rates of etchants and the power change the plasma densities and fluxes, and ion energy, and change the etching properties and etching selectivity. Hence, it would have been obvious to one with ordinary skilled in the art to vary the flow rates of etchants and process parameters in order to produce desired etch rate selectivity." (Final Official Action at Page 3).

While Liu discloses that the capability to control the composition and conformal deposition of polymeric photoresist improves the selectivities to the underlayers made of materials other than SiO_2, such as Si_3N_4, polysilicon, and metal silicide, Liu is ultimately concerned with providing high selectivity for etching oxide relative to photoresist. (Column 4, Line 55 - Column 5, Line 6). Thus, Liu discloses a photoresist selectivity, measured as the ratio of (1) the oxide thickness etched through plus a distance correspond to the over-etch time used to (2) the depth of the lower photoresist facet corner from the original photoresist surface, as large as greater than 10:1 (Column 9, Lines 9-15).

Accordingly, it is respectfully submitted that Liu in view of Schmitt does not disclose or suggest the presently claimed etch rate selectivity of dielectric to silicon nitride of at least 10 (Claim 3), etch rate selectivity of BPSG to flat and corner

portions of silicon nitride of at least 15 (Claim 19), or etch rate selectivity of dielectric to stop layer of greater than 30:1 (Claim 21).

2. **Rejection of Claims 8 and 14 under 35 U.S.C. § 103(a)**

Claim 8 recites the method of Claim 1, wherein the C_xF_y gas is at least C_4F_6, the oxygen containing gas is at least O_2 and the carrier gas is Ar, the etchant gas being supplied to the plasma etch reactor through the showerhead electrode at flow rates of 10 to 25 sccm C_4F_6, 5 to 20 sccm O_2 and 50 to 300 sccm Ar. Claim 14 recites the method of Claim 1, wherein the etchant gas includes CO supplied to the plasma etch reactor at a rate of 50 to 500 sccm CO.

Similar to pressure and temperature as noted above, the final Official Action asserts that etchant flow rates

> "are recognized result-effective variables, and commonly determined by routine experiment. The process of conducting routine experimentations so as to produce an expected result is obvious to one of ordinary skill in the art. In the absence of showing criticality or new, unexpected results, it is the examiner's position that a person having ordinary skill in the art at the time of the claimed invention would have found it obvious to modify Liu by performing routine experiments ... to obtain optimal result in order to produce the best etched product achievable." (Final Official Action at Page 4).

a. **Claim 8**

Liu discloses: (1) a C_4F_6 flow of 30 SCCM, an O_2 flow of 18 SCCM, and an Ar flow of 700 SCCM (Table 1), (2) a C_4F_6 flow of 30 SCCM, an O_2 flow of 23 SCCM, and an Ar flow of 700 SCCM (Table 2), (3) a C_4F_6 flow of 28 SCCM, an O_2 flow of 24 SCCM, and an Ar flow of 500 SCCM in Step 1 and a C_4F_6 flow of 28 SCCM, an O_2 flow of 20 SCCM, and an Ar flow of 500 SCCM in Step 2 (Table 3), and (4) a C_4F_6 flow of 23 SCCM, an O_2 flow of 18 SCCM, and an Ar flow of 500 SCCM (Table 4). Specifically, Liu discloses, "The flow of argon relative to that of hexafluorobutadiene[3]

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[3] C_4F_6

is high, at least ten times greater and preferably twenty times greater." (Column 10, Lines 28-30). Accordingly, it is respectfully submitted that Liu in view of Schmitt does not disclosure or suggest the presently claimed flow rates of 10 to 25 sccm C_4F_6, 5 to 20 sccm O_2 and 50 to 300 sccm Ar.

b. **Claim 14**

While Liu discloses inclusion of CO in the etching gas mixture (See, for example, Column 6, Lines 1-2), Liu does not disclose the flow rate at which CO may be added. Accordingly, it is respectfully submitted that there is no teaching in Liu which would have lead a person of ordinary skill in the art to supply CO at a rate of 50 to 500 sccm CO.

3. **Rejection of Claims 2, 11, and 12 under 35 U.S.C. § 103(a)**

Claim 2 recites the method of Claim 1, wherein the openings comprise vias, contacts, and/or trenches of a dual damascene structure, a self-aligned contact structure or self-aligned trench structure and the showerhead electrode is supplied 0 to 3000 watts of RF energy and the bottom electrode is supplied 0 to 3000 watts of RF energy. Claim 11 recites the method of Claim 1, wherein the dual frequency capacitively coupled plasma reactor is operated with a top electrode power of 200 to 3000 W and a bottom electrode power of 50 to 3000 W for etching the openings. Claim 12 recites the method of Claim 1, wherein the dual frequency capacitively coupled plasma reactor is operated with a top electrode power of 1000 to 2000 W, and a bottom electrode power of 1000 to 2000 W for etching the openings.

Similar to pressure, temperature, and etchant flow rates as noted above, the final Official Action asserts that RF energy is a recognized result-effective variable,

> "commonly determined by routine experiment. The process of conducting routine experimentations so as to produce an expected result is obvious to one of ordinary skill in the art. In the absence of showing criticality or new, unexpected results, it is the examiner's position that a person having ordinary skill in the art at the time of the claimed invention would have found it obvious to modify Liu by performing routine experiments ... to obtain

> optimal result in order to produce the best etched product achievable." (Final Official Action at Page 4).

Liu discloses a preferred range of RF power for maximizing photoresist selectivity of 1650 to 2100 W for a 200-mm diameter wafer, and that powers generally scale as the area of the wafer. (Column 11, Lines 32-35). As discussed above, Schmitt does not disclose etching a dielectric layer and while Schmitt discloses various plasma reactors, Schmitt fails to disclose the claimed electrode power.

It is respectfully submitted that Liu in view of Schmitt does not disclose or suggest supplying the showerhead electrode 0 to 3000 watts of RF energy and the bottom electrode 0 to 3000 watts of RF energy, operating with a top electrode power of 200 to 3000 W and a bottom electrode power of 50 to 3000 W, or operating with a top electrode power of 1000 to 2000 W and a bottom electrode power of 1000 to 2000 W.

4. **Rejection of Claim 18 under 35 U.S.C. § 103(a)**

Claim 18 recites the method of Claim 1, wherein the C_xF_y is C_4F_6 and the oxygen containing gas is supplied to the plasma etch chamber in an amount sufficient to avoid etch stop during etching of the openings.

The Official Action Mailed August 30, 2004, asserts that "[a]s to dependent claim 18, in order to complete the etching of the openings, keeping an amount of etchants sufficient to avoid etch stop is expected in the method of Liu." (Official Action Mailed August 30, 2004, at Page 4). Accordingly, the final Official Action acknowledges that Liu fails to teach supplying oxygen containing gas to the plasma etch chamber in an amount sufficient to avoid etch stop during etching of the openings.

Liu discloses that during fluorocarbon etching of holes in oxide, too little polymerization will degrade protection to the sidewall and selectivity to photoresist, nitride, and other non-oxide materials, while a slight excess of polymerization in very high aspect-ratio holes will cause etch stop towards the bottom of the hole. (Column 5, Lines 24-35). Liu further discloses that in order to control the degree of polymerization and the composition of polymer formed during fluorocarbon etching of

holes in oxide, it is often desirable to combine a polymer-oxidizing gas, such as gaseous oxygen (O_2) or carbon monoxide (CO), with the beneficial effects of a low-F/C fluorocarbon and a high carrier gas fraction. (Column 5, Line 35 – Column 6, Line 2). In particular, Liu discloses that an amount of argon at least 10 times that of C_4F_6, preferably at least 20 times will help increase the etch stop margin. (Column 9, Lines 2-4).

In contrast, the present application specifically discloses that polymer build-up can be reduced by the synergistic effect of breaking up polymer with oxygen in the etching gas mixture. (Present Application at Page 18, Line 1-11). Thus, oxygen is added in an amount effective to control the etch rate selectivity of the etching gas chemistry. That is, the oxygen is effective to prevent etch stop by reacting with polymer at the bottom of the etched openings. (Present Application at Page 18, Line 12-15).

Contrary to the Examiner's assertion that "in order to complete the etching of the openings, keeping an amount of etchants sufficient to avoid etch stop is expected in the method of Liu," it is respectfully submitted that Liu in view of Schmitt does not disclose or suggest supplying oxygen in an amount sufficient to avoid etch stop during etching of the openings.

E. **Conclusion**

For the reasons set forth above, it is respectfully submitted that the pending claims are allowable. Reversal of the rejections is respectfully requested.

Respectfully submitted,

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Table of Contents

VIII. CLAIMS APPENDIX

The Appealed Claims

1. (Previously Presented) A method of etching a dielectric layer with selectivity to an underlying stop layer, comprising:

supporting a semiconductor substrate in a plasma etch chamber of a plasma etch reactor, wherein the plasma etch reactor is a capacitively coupled plasma reactor having a powered showerhead electrode and/or a powered bottom electrode, the substrate including a dielectric layer over a stop layer;

supplying an etchant gas to the plasma etch chamber with the showerhead electrode; and

etching openings in the dielectric layer by energizing the etchant gas into a plasma state by capacitively coupling RF energy into the plasma etch chamber, the etchant gas comprising a hydrogen-free fluorocarbon gas represented by C_xF_y gas wherein $y/x \leq 1.5$, an oxygen-containing gas and optional carrier gas,

wherein the plasma etch reactor comprises a dual frequency capacitively coupled plasma reactor and RF energy is supplied at two different frequencies to either the bottom electrode or at different first and second frequencies to the showerhead electrode and bottom electrode, and

wherein the pressure in the plasma etch reactor is 50 to 100 mTorr and temperature of the substrate support is +20°C to +60°C.

2. (Previously Presented) The method of Claim 1, wherein the openings comprise vias, contacts, and/or trenches of a dual damascene structure, a self-aligned contact structure or self-aligned trench structure and the showerhead electrode is supplied 0 to 3000 watts of RF energy and the bottom electrode is supplied 0 to 3000 watts of RF energy.

3. (Previously Presented) The method of Claim 1, wherein the stop layer is silicon nitride and the etch rate selectivity of the dielectric to the silicon nitride is at least 10.

4. (Previously Presented) The method of Claim 1, wherein the dielectric layer comprises a doped or undoped silicon oxide layer or low-k material and the stop layer comprises a silicon nitride layer.

5. (Canceled)

6. (Canceled)

7. (Previously Presented) The method of Claim 1, wherein the etchant gas is nitrogen-free, the C_xF_y gas is at least C_4F_6, the oxygen containing gas is at least O_2 and the carrier gas is Ar, the etchant gas being supplied to the plasma etch reactor through the showerhead electrode at flow rates of 2 to 50 sccm C_4F_6, 2 to 50 sccm O_2 and 50 to 800 sccm Ar.

8. (Previously Presented) The method of Claim 1, wherein the C_xF_y gas is at least C_4F_6, the oxygen containing gas is at least O_2 and the carrier gas is Ar, the etchant gas being supplied to the plasma etch reactor through the showerhead electrode at flow rates of 10 to 25 sccm C_4F_6, 5 to 20 sccm O_2 and 50 to 300 sccm Ar.

9. (Original) The method of Claim 1, wherein a ratio of flow rates of the C_xF_y to oxygen containing reactant is 0.5:1 to 5:1.

10. (Original) The method of Claim 1, wherein a ratio of flow rates of the C_xF_y to oxygen containing reactant is 1:1 to 2:1.

11. (Previously Presented) The method of Claim 1, wherein the dual frequency capacitively coupled plasma reactor is operated with a top electrode power of 200 to 3000 W and a bottom electrode power of 50 to 3000 W for etching the openings.

12. (Previously Presented) The method of Claim 1, wherein the dual frequency capacitively coupled plasma reactor is operated with a top electrode power of 1000 to 2000 W, and a bottom electrode power of 1000 to 2000 W for etching the openings.

13. (Canceled)

14. (Original) The method of Claim 1, wherein the etchant gas includes CO supplied to the plasma etch reactor at a rate of 50 to 500 sccm CO.

15. (Original) The method of Claim 1, wherein the C_xF_y is either C_4F_6 or C_6F_6.

16. (Original) The method of Claim 1, wherein the C_xF_y is C_4F_6 and the oxygen containing gas is O_2, the C_4F_6 and O_2 being supplied to the plasma etch reactor at flow rates having a ratio of C_4F_6:O_2 of 0.5:1 to 5:1.

17. (Original) The method of Claim 1, wherein the C_xF_y is C_4F_6 and the oxygen containing gas is O_2, the C_4F_6 and O_2 being supplied to the plasma etch reactor at flow rates having a ratio of C_4F_6:O_2 of 1:1 to 2:1.

18. (Original) The method of Claim 1, wherein the C_xF_y is C_4F_6 and the oxygen containing gas is supplied to the plasma etch chamber in an amount sufficient to avoid etch stop during etching of the openings.

19. (Previously Presented) The method of Claim 1, wherein the etched openings open onto flat and corner portions of the stop layer, the dielectric layer comprises BPSG and the stop layer comprises silicon nitride, the etch rate selectivity of the BPSG to the flat and corner portions of the silicon nitride being at least 15.

20. (Original) The method of Claim 1, wherein the dielectric layer comprises BPSG and the stop layer comprises silicon nitride, the C_xF_y gas being C_4F_6 and the oxygen containing gas being O_2, the C_4F_6 and O_2 being supplied to the plasma etch reactor at flow rates having a ratio of O_2:C_4F_6 of 0.5 to 1.2.

21. (Previously Presented) The method of Claim 1, wherein the etch rate selectivity of the dielectric to the stop layer is greater than 30:1.

22. (Previously Presented) The method of Claim 1, wherein the etching of the dielectric layer is carried out in a single step.

23. (Previously Presented) The method of Claim 1, wherein the etchant gas is hydrogen-free.

24. (Previously Presented) A method of etching a dielectric layer with selectivity to an underlying stop layer, comprising:

supporting a semiconductor substrate in a plasma etch reactor, wherein the plasma etch reactor is a capacitively coupled plasma reactor having a powered showerhead electrode and/or a powered bottom electrode, the substrate including a dielectric layer over a stop layer;

supplying an etchant gas to the plasma etch chamber; and

etching openings in the dielectric layer by energizing the etchant gas into a plasma state, the etchant gas consists essentially of a hydrogen-free fluorocarbon gas represented by C_xF_y gas wherein $y/x \leq 1.5$, an oxygen-containing gas and optional carrier gas,

wherein the plasma etch reactor comprises a dual frequency capacitively coupled plasma reactor and RF energy is supplied at two different frequencies to either the bottom electrode or at different first and second frequencies to the showerhead electrode and bottom electrode, and

wherein the pressure in the plasma etch reactor is 50 to 100 mTorr and temperature of the substrate support is +20°C to +60°C.

25. (Previously Presented) A method of etching a dielectric layer with selectivity to an underlying stop layer, comprising:

supporting a semiconductor substrate in a plasma etch reactor, wherein the plasma etch reactor is a capacitively coupled plasma reactor having a powered showerhead electrode and/or a powered bottom electrode, the substrate including a dielectric layer over a stop layer;

supplying an etchant gas to the plasma etch chamber; and

etching openings in the dielectric layer by energizing the etchant gas into a plasma state, the etchant gas consists of a hydrogen-free fluorocarbon gas represented by C_xF_y gas wherein $y/x \leq 1.5$, an oxygen-containing gas and optional carrier gas,

wherein the plasma etch reactor comprises a dual frequency capacitively coupled plasma reactor and RF energy is supplied at two different frequencies to either the bottom electrode or at different first and second frequencies to the showerhead electrode and bottom electrode, and

wherein the pressure in the plasma etch reactor is 50 to 100 mTorr and temperature of the substrate support is +20°C to +60°C.

26. (Previously Presented) The method of Claim 1, wherein the etchant gas is free of hydrogen-containing fluorocarbon gas.

27. (Previously Presented) The method of Claim 1, wherein the etchant gas is free of fluorocarbon gas represented by C_xF_y, wherein $y/x > 1.5$.